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Multi-Regression Factors Influencing Textile Dye Adsorption on Activated Carbon

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Abstract

Waste from textile plants contains high concentrations of textile dyes, which may be harmful to the environment. Activated carbon can be used to remove the dyes from such wastewater. Dyes can adsorb onto activated carbon, making the wastewater safer for the environment and health of those drinking it. This experiment researched the factors affecting adsorbance onto the activated carbon and what conditions work best in eliminating the dye. The aim for this experiment is to develop a mathematical model to predict the adsorbance of dye onto activated carbon. The factors studied affecting this include types of dye, salinity, pH, type of carbon, and time the mixture is in contact with the carbon. Using factorial analysis, two different dyes, two salinities, three pH's, and three different types of carbon were tested under three different time spans.

Introduction

Wastewater from the textile industry contains large concentrations of commercial dyes, which can be very harmful to the environment. The pollution from such dyes in surrounding bodies of water can be fatal to aquatic animals as well as any people intending to drink it. This project was aimed at finding a safe and efficient way to remove these dyes from wastewater. A solution to this environmental issue involves the use of activated carbon and the adsorption of the dyes onto the carbon. In theory, the relatively large dye molecules will adsorb onto the activated carbon, removing it from solution.

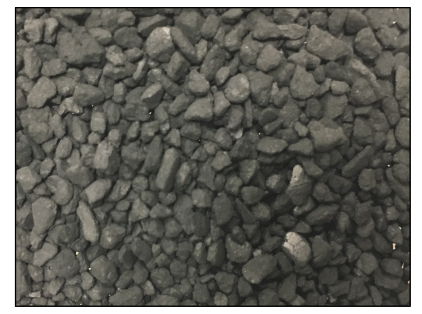
Various literature articles state that a variety of factors influence activated carbon adsorption. These include type of carbon, type of dye and its properties, pH, salinity, temperature, and time the dye is in contact with the activated carbon. In this experiment, we want to measure which factors and to what extent each factor had an effect on the adsorption. The factors we focused on throughout this study were time, type of carbon, type of dye, pH, and salinity. Using factorial analysis and analysis of variance (ANOVA), we can find out which of these are most important to the experiment by looking at multiple factors simultaneously. The ultimate goal is to create a mathematical equation for the factors affecting activated carbon adsorption.

Methods & Materials

Activated Carbons: (supplied by CalgonCarbon, Pittsburgh, PA, USA)

Filtrasorb 600M

SGL 8x30



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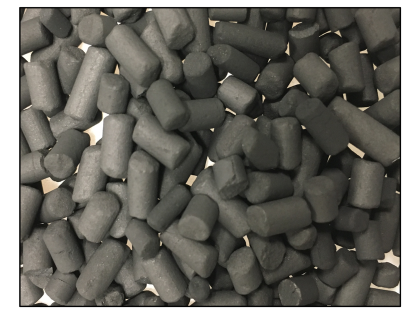
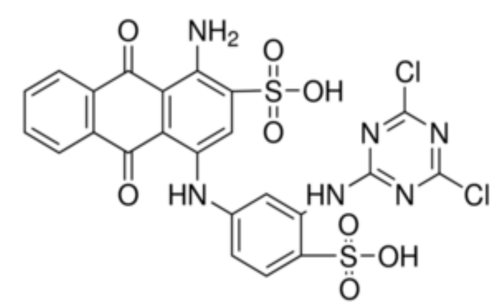
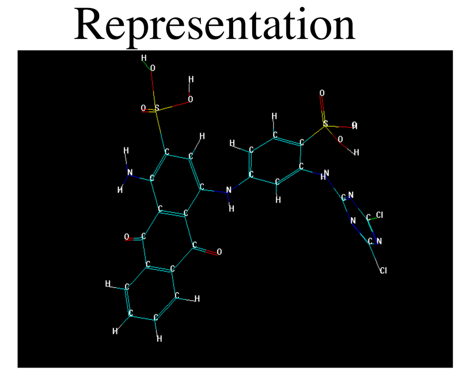


Dyes:

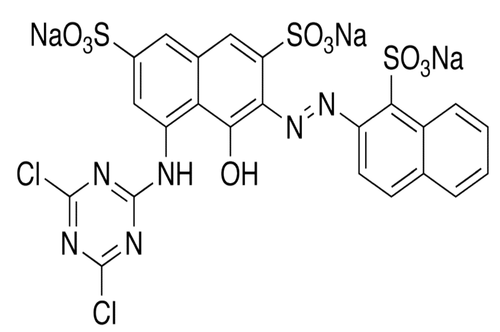
2-D Representation | Hyperchem 3-D Representation

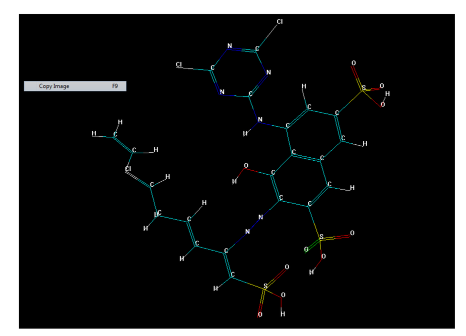
Procion Blue 406





Procion Red 308





To prepare the initial dye solutions, 1.5 g of each dye was dissolved in 6 L of tap water. Each six-liter bottle of dye was split in half, with one left untouched and one combined with enough sea salt to make the solution 1% salinity. Once the salt was fully dissolved, the solution was split again in one-liter bottles. The pH was adjusted to either 4.0, 7.0 or 10.0 using minimal amounts of dilute HCl or NaOH. With these solutions, 216 isotherm runs were performed, including duplicates for every run.

For each run, 50 mL of the particular solution was measured out precisely and added to 0.5 g of activated carbon. With a magnetic stir bar, the solution and activated carbon mixed on low speed of a multi-magnetic stir plate for either 2, 4, or 8 hours. After the allotted time, an aliquot of each sample was removed and then centrifuged to remove excess activated carbon particles suspended in solution. The absorbance of each sample was then measured at maximum wavelength using a Shimadzu UV-Vis Spectrometer UV-1800.

Design of Experiment

In this study, a mathematical equation to determine the adsorption of textile dyes on activated carbon was researched. Using Minitab Software, we were able to determine the importance of pH, salinity, carbon, dye and time. The various levels of these factors are given in table 1 below. The types of activated carbon used in this experiment were Filtrasorb 600M (F600), SGL 8x30 (SGL), and AP 4-60 (4-60), which vary tremendously in size. The dyes were Procion Blue 406 (B406) and Procion Red 308 (R308). These are very large molecules, both their two-dimensional and three-dimensional structures are shown in the figures to the left. The solutions were either 0% or 1% salinity, by weight. The pH of the solutions were either 4, 7, or 10. The time the activated carbon was in contact with each solution was 2, 4, or 8 hours.

216 runs are performed under the below conditions and the run order is randomized to ensure unbiased. The first 10 runs are displayed in table 2.

Table 1: Factors and Levels

Type of Activated Carbon	F600	SGL	4-60
Type of Dye	B406	R308	-----
Salinity, %	0.0	1.0	-----
Time, hours	2.0	4.0	8.0
pH	4.0	7.0	10

Table 2: Design of Experiment for First 10 Runs*

Run Order	Dye	pH	Salinity, %	Activated Carbon	Time, hours
1	B406	10	1.0	F600	2
2	B406	4	0.0	SGL	2
3	R308	7	1.0	SGL	2
4	B406	4	1.0	4-60	8
5	R308	7	0.0	SGL	4
6	R308	10	1.0	F600	2
7	R308	4	0.0	F600	4
8	R308	4	0.0	SGL	2
9	R308	7	0.0	F600	4
10	R308	7	0.0	F600	4

*order of experiment is random

Results & Discussion

Using MiniTab_{16} and Analysis of Variance (ANOVA), we were able to determine which parameters were deemed most important in this experiment. The ANOVA analysis is able to test multiple parameters simultaneously. Table 3 displays the ANOVA data, with the p values ranging from 0.00 to 0.80. Given these values, the parameter is said to be significant when the value is less than 0.05. The two parameters themselves that are extremely significant, based on their p values, are the type of carbon and the time. When looking at the interaction of multiple parameters , type of carbon and time is significant as well as type of dye and time. These values are highlighted in table 3.

Table 3: Analysis of Variance

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Carbon	2	2632.40	2632.40	1316.20	287.91	0.000
Dye	1	55.15	55.15	55.15	12.06	0.001
pH	2	12.95	12.95	6.47	1.42	0.245
Salinity	1	19.26	19.26	19.26	4.21	0.042
Time	2	840.63	840.63	420.32	91.94	0.000
Carbon*Dye	2	101.14	101.14	50.57	11.06	0.000
Carbon*pH	4	7.52	7.52	1.88	0.41	0.800
Carbon*Salinity	2	38.95	38.95	19.47	4.26	0.016
Carbon*Time	4	148.60	148.60	37.15	8.13	0.000
Dye*pH	2	65.33	65.33	32.67	7.15	0.001
Dye*Salinity	1	14.43	14.43	14.43	3.16	0.077
Dye*Time	2	115.15	115.15	57.58	12.59	0.000
pH*Salinity	2	16.78	16.78	8.39	1.84	0.162
pH*Time	4	80.28	80.28	20.07	4.39	0.002
Salinity*Time	2	6.98	6.98	3.49	0.76	0.468

In looking at the effect of the carbon and time of the adsorption of activated carbon, certain relationships can be made. In the experiment, samples were run for 2, 4, and 8 hours. The longer time the carbon was in contact with the dye in solution, the more carbon was adsorbed. The form of the carbon was significant because the more particulate carbons were able to adsorb the dye molecules easier. The larger activated carbon adsorbed less dye solution. According to the ANOVA analysis, pH and salinity did not effect the adsorption. We speculate that this is because both the salt ions and the H^+ ions from the pH are very small. Because of their small size, it is likely that these ions were able to migrate into small micropores of the carbon as opposed to adsorbing onto the surface like the large dye molecules did.

Conclusion

Overall, this research project was successful because we were able to find which factors influence activated carbon adsorbtion on commercial dyes. We found that the type of carbon, the type of dye, and the amount of time they are in contact have a major impact on the adsorbtion. However, factors such as salinity and pH did not seem to affect the adsorbtion at all. As this study continues, the goal is to come up with a working mathematical equation to state this and the amount each factor affects it.